



The Importance of Leptoquarks Explained

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ATLAS Collaboration

at the Large Hadron Collider

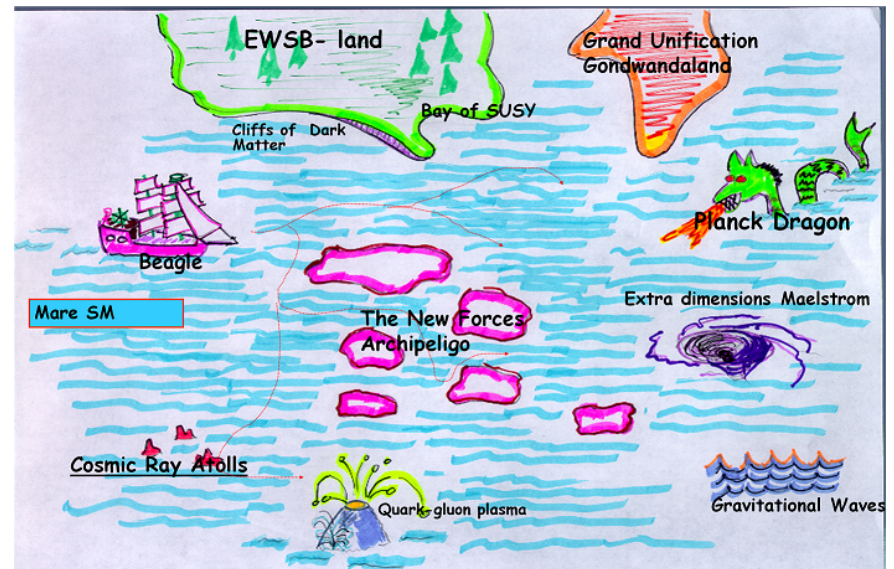
presentation to Borders Science Café

January 30, 2011



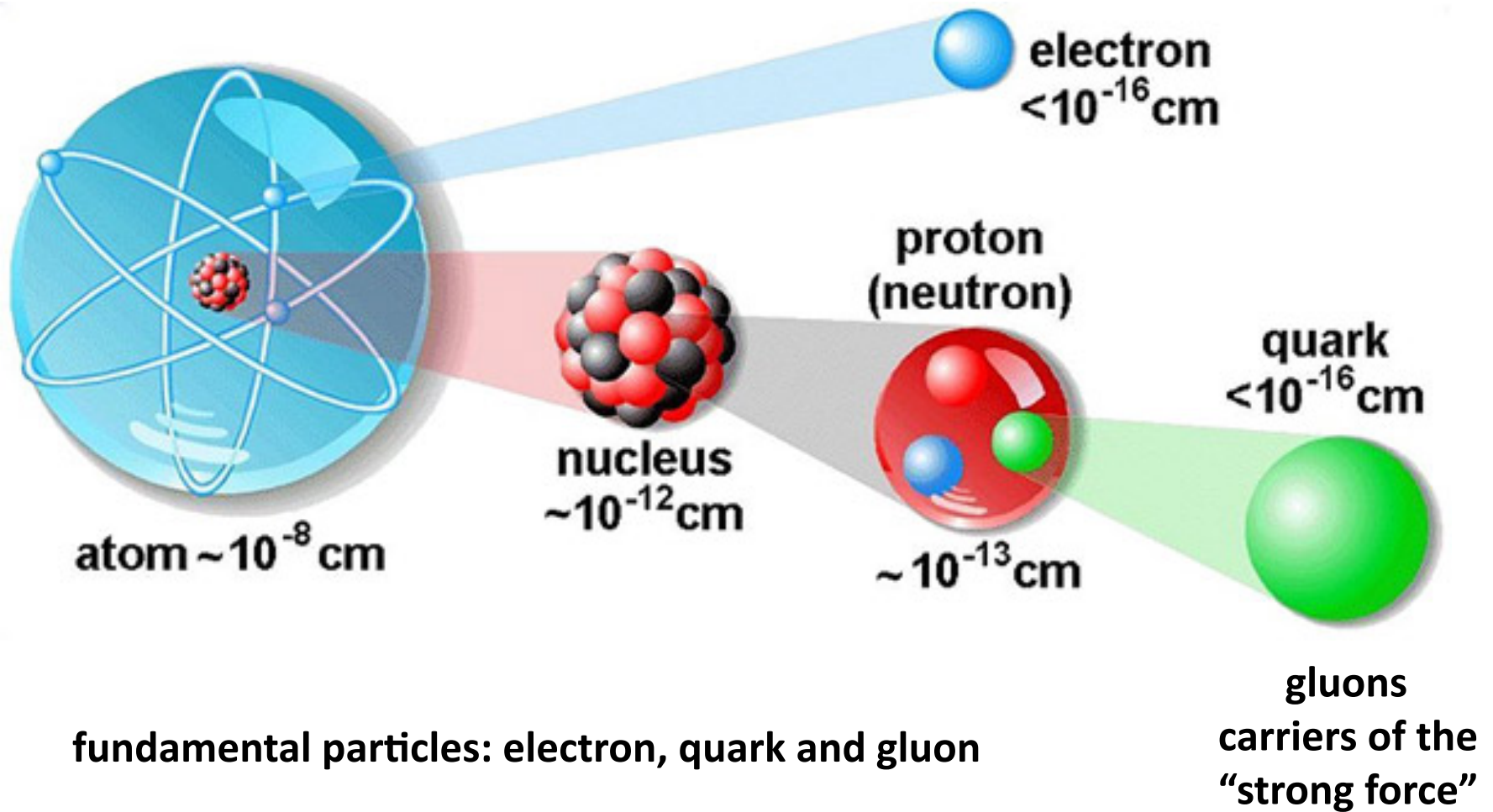
The Importance of Leptoquarks Explained

- Physics Background
- What are Leptoquarks – and why are they important?
- How is ATLAS used in a leptoquark search?
- What are the challenges of a leptoquark search?

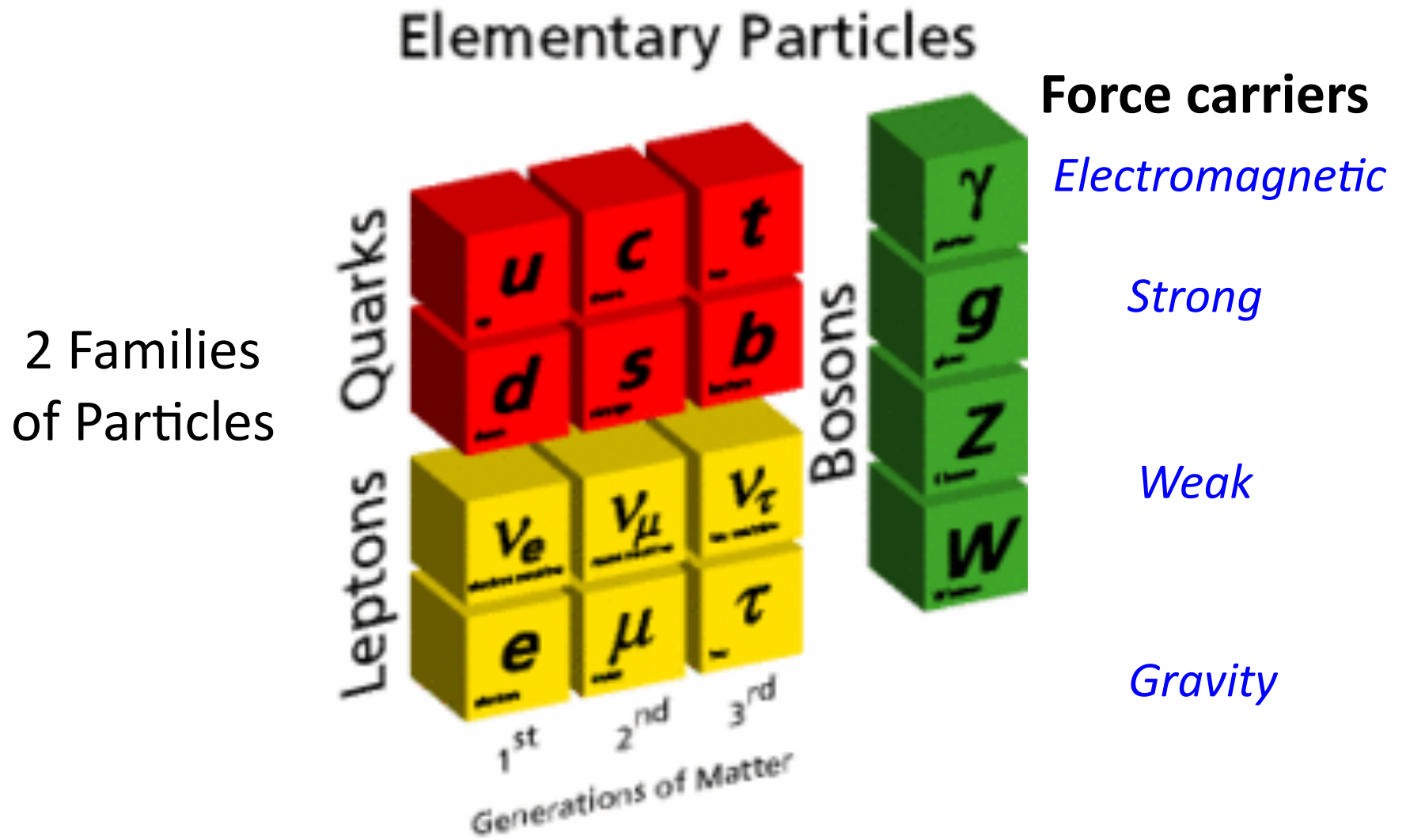




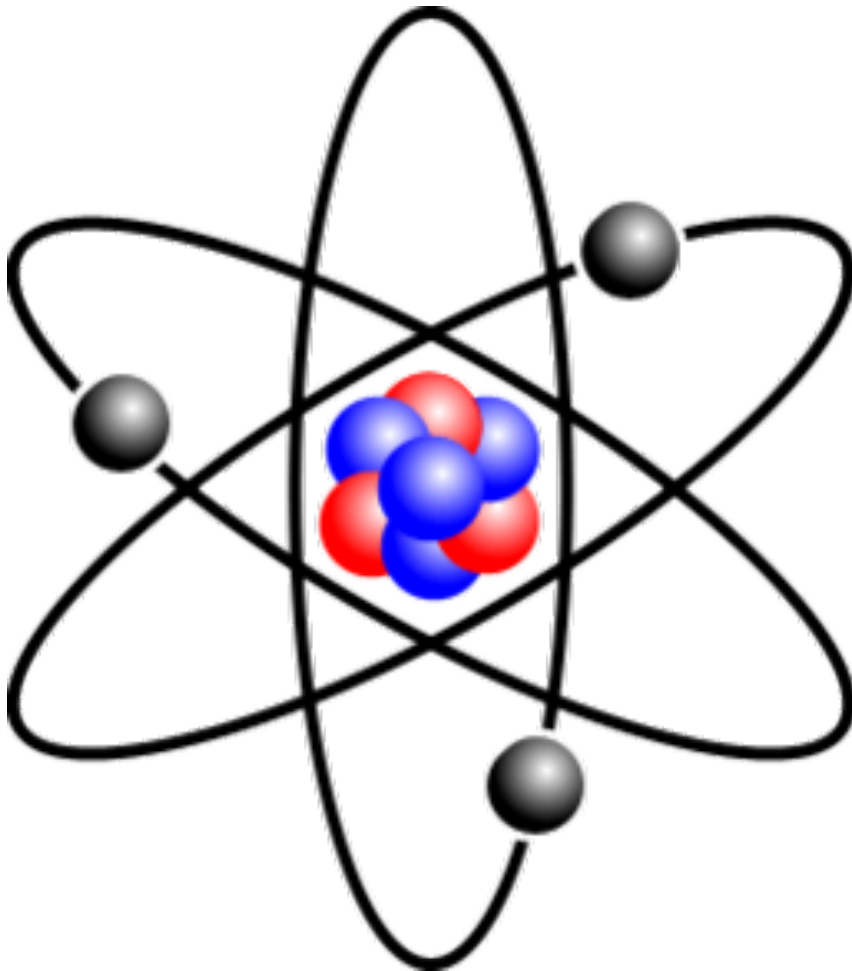
Physics Background: the Inner Workings of the Atom



The Standard Model

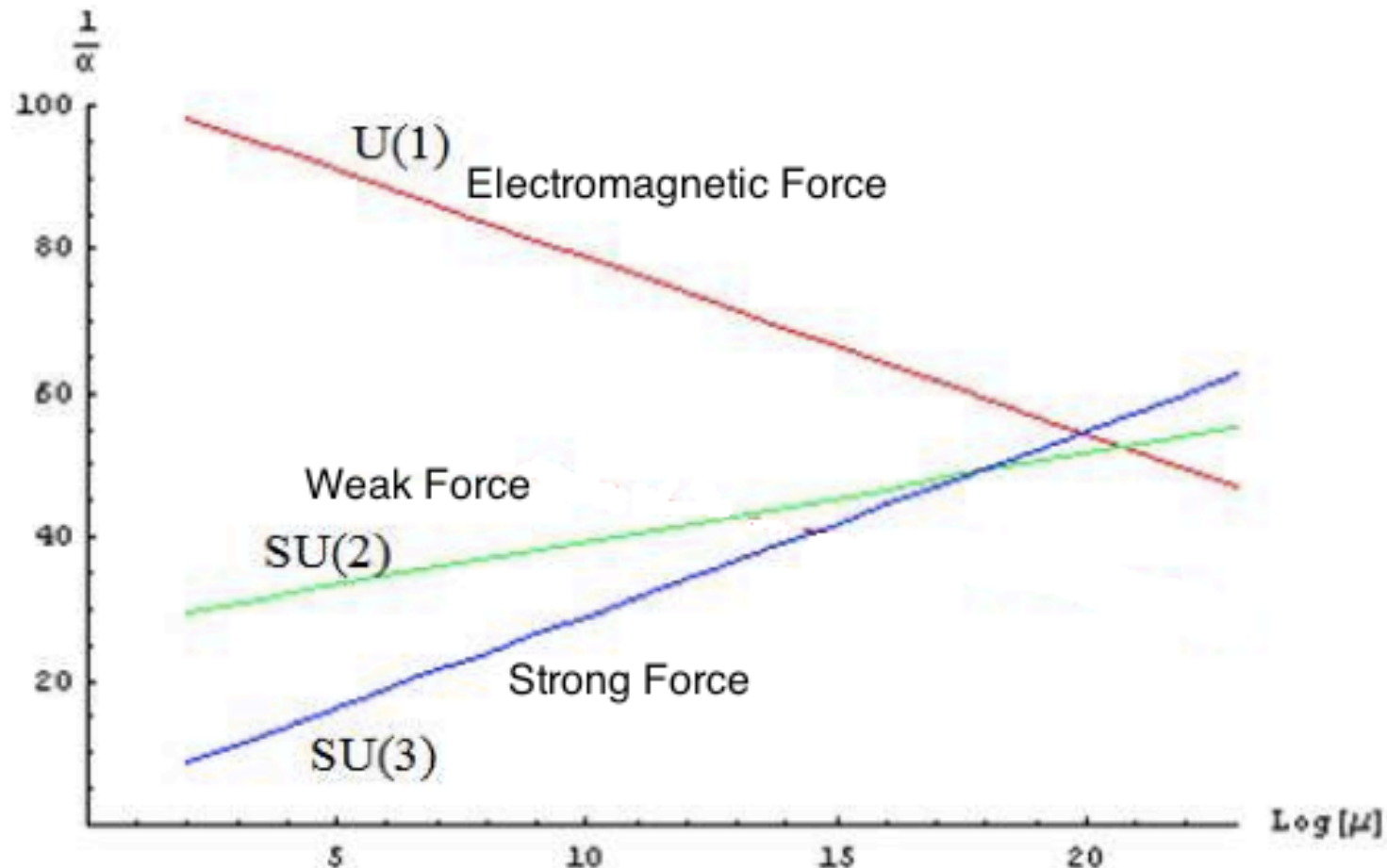


Physics Background: The Four Forces of Nature



- The Forces (from Thomas' talk)
 - Strong
 - 1 strength with 10^{-15} m (~nucleus) range
 - Electromagnetic
 - 10^{-3} strength with infinite range
 - Weak
 - 10^{-6} strength with 10^{-18} m (~0.1% dia. proton) range
 - Gravity
 - 10^{-39} strength with infinite range
- Forces represented by a constant that couples to the force
 - dependent on temperature

Physics Background: The Coupling of the Forces

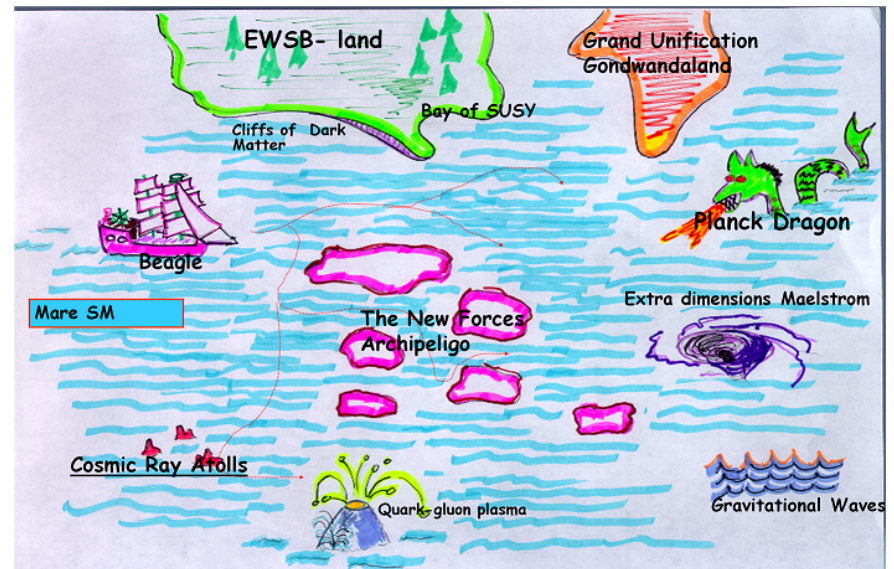


Physics Background: The Coupling of the Forces

- CHALLENGE: So what do we notice about the couplings?
- All the forces seem to come together at a very high temperature (energy)
 - $\sim 10^{-30}$ seconds after the big bang
- The case for a Grand Unified Theory (GUT)
 - Unifies the forces into one force
 - Lots of other particles result... one of which is a Leptoquark which unifies quarks and leptons

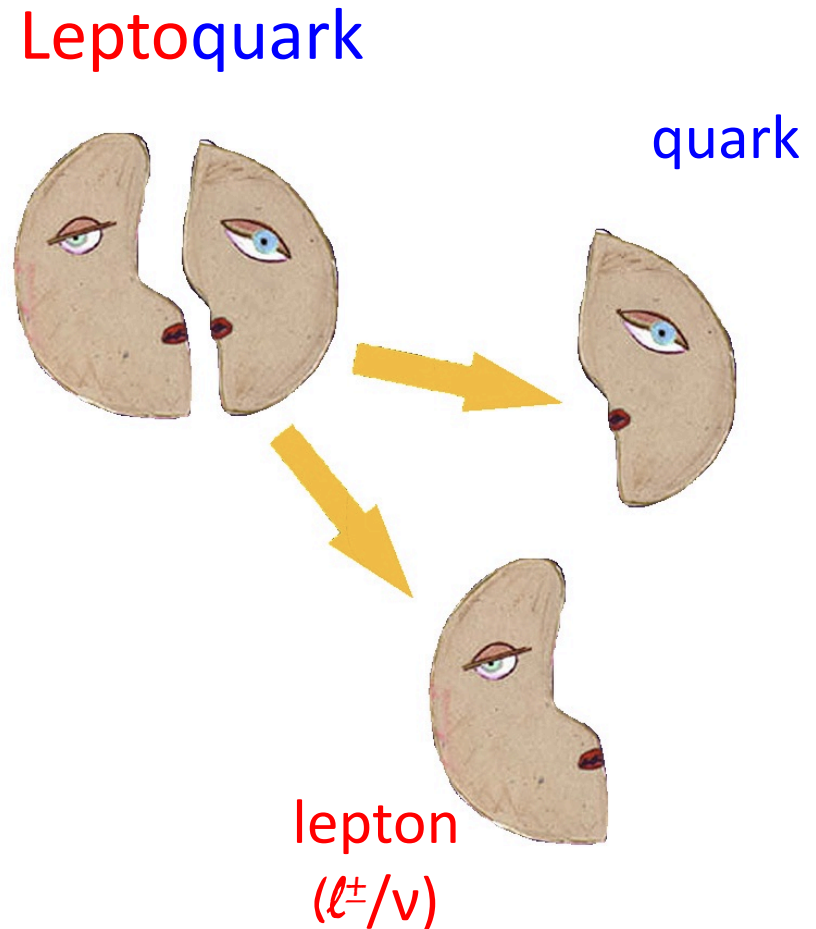
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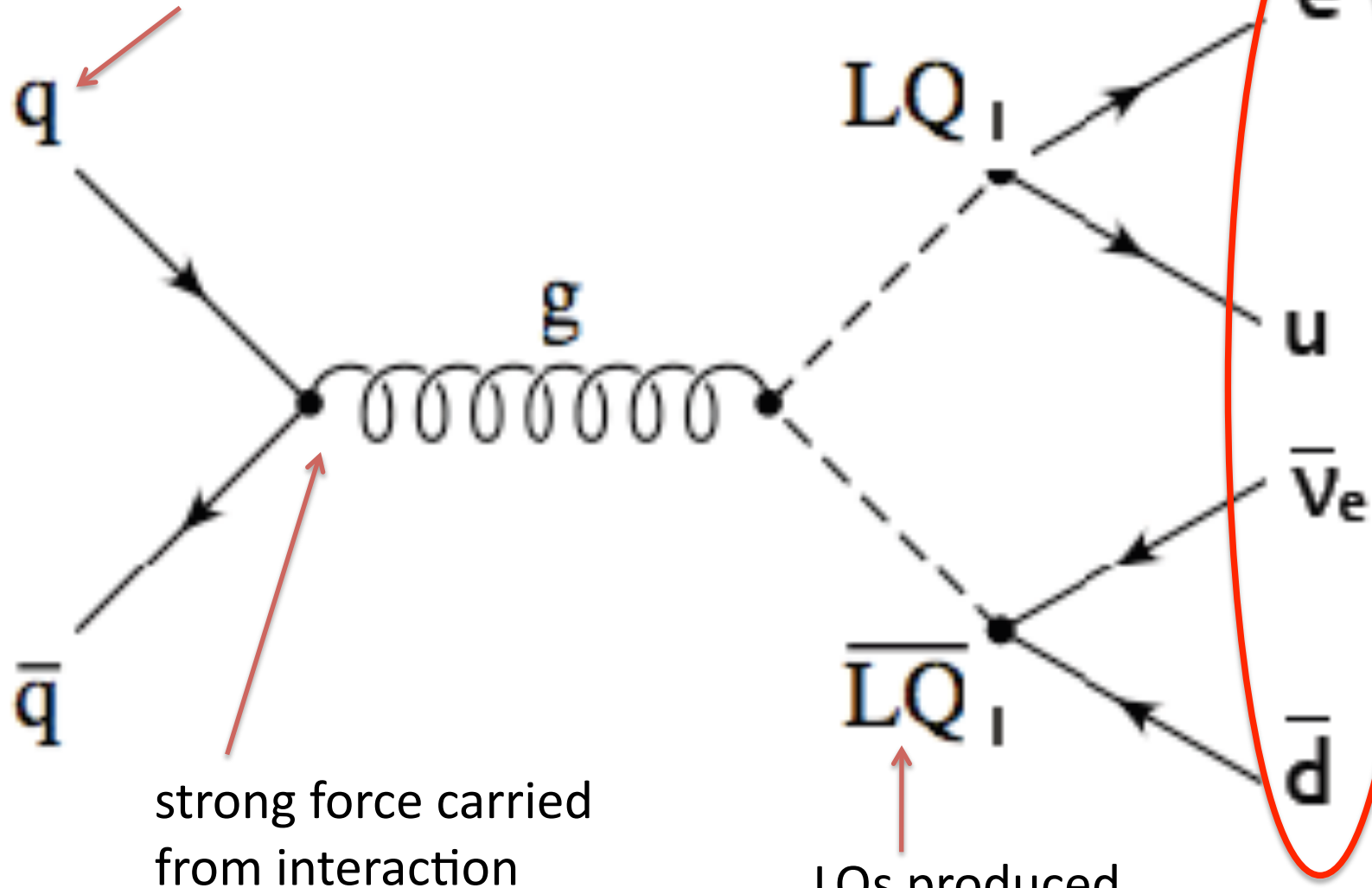
What are Leptoquarks and why are they important?

- What: the hypothetical particle defined
- Why: New physics beyond the standard model
- So How does this happen:
 - Quarks from protons provided by LHC collide
 - Interact via the strong force
 - Leptoquarks are created in pairs
 - Leptoquarks decay



What are Leptoquarks? A physicist's view

quarks provided by LHC

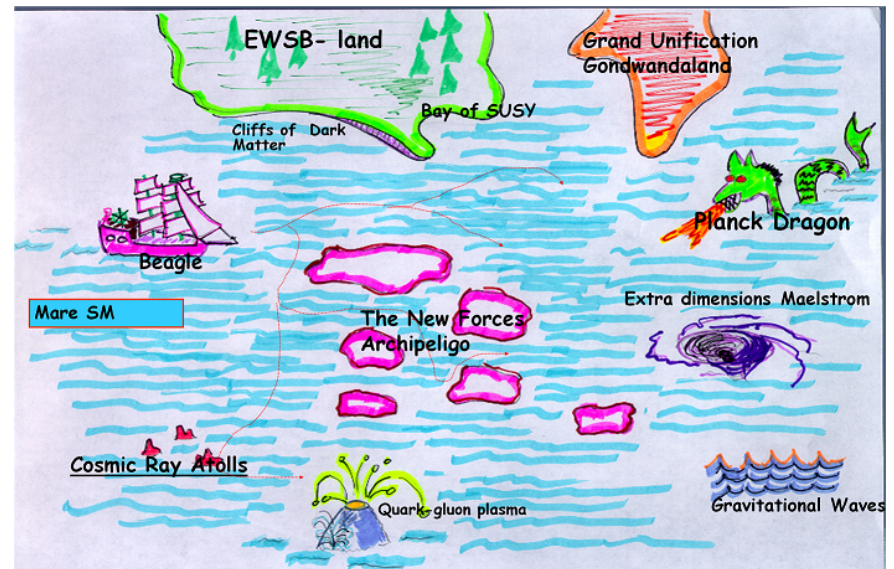


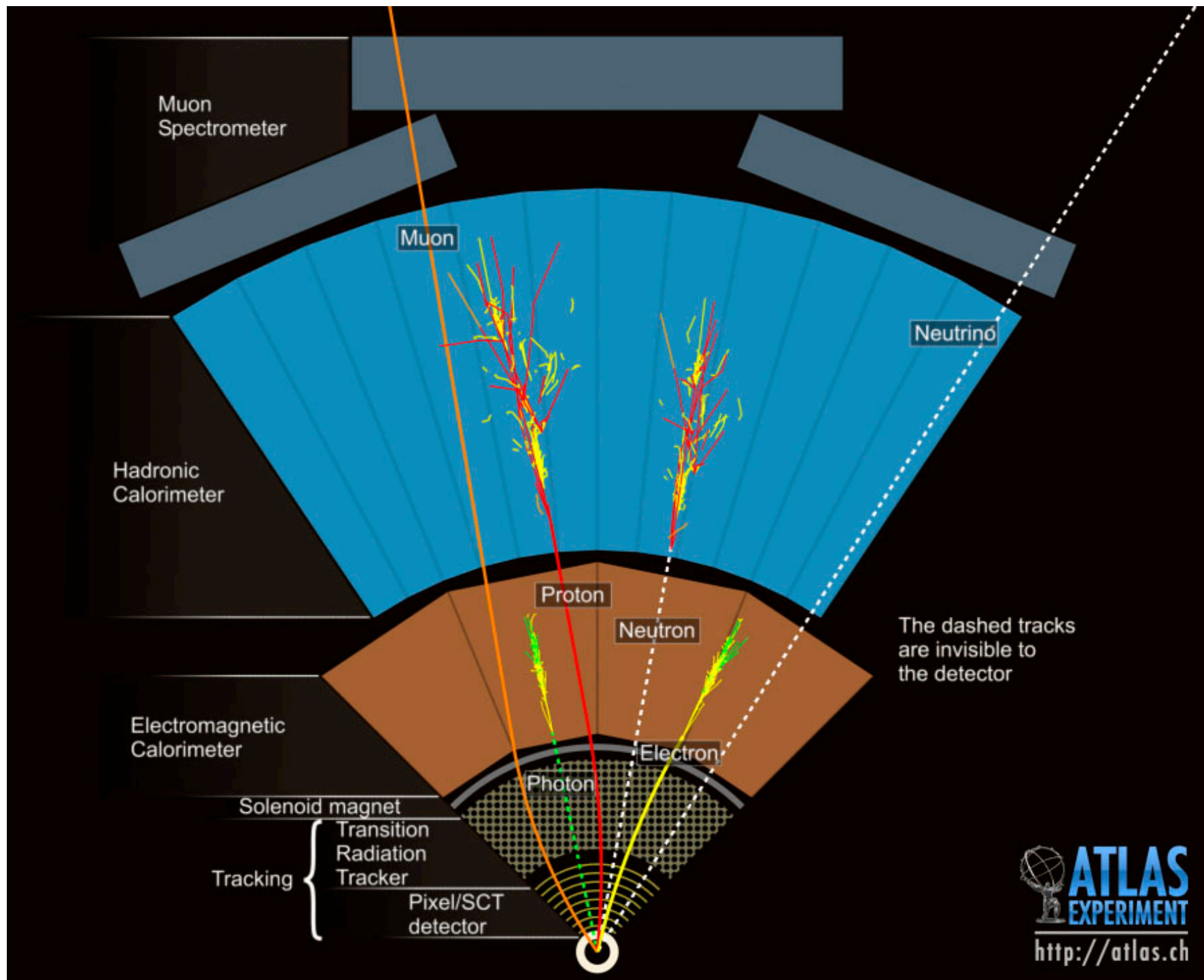
strong force carried
from interaction

LQs produced
and then decay

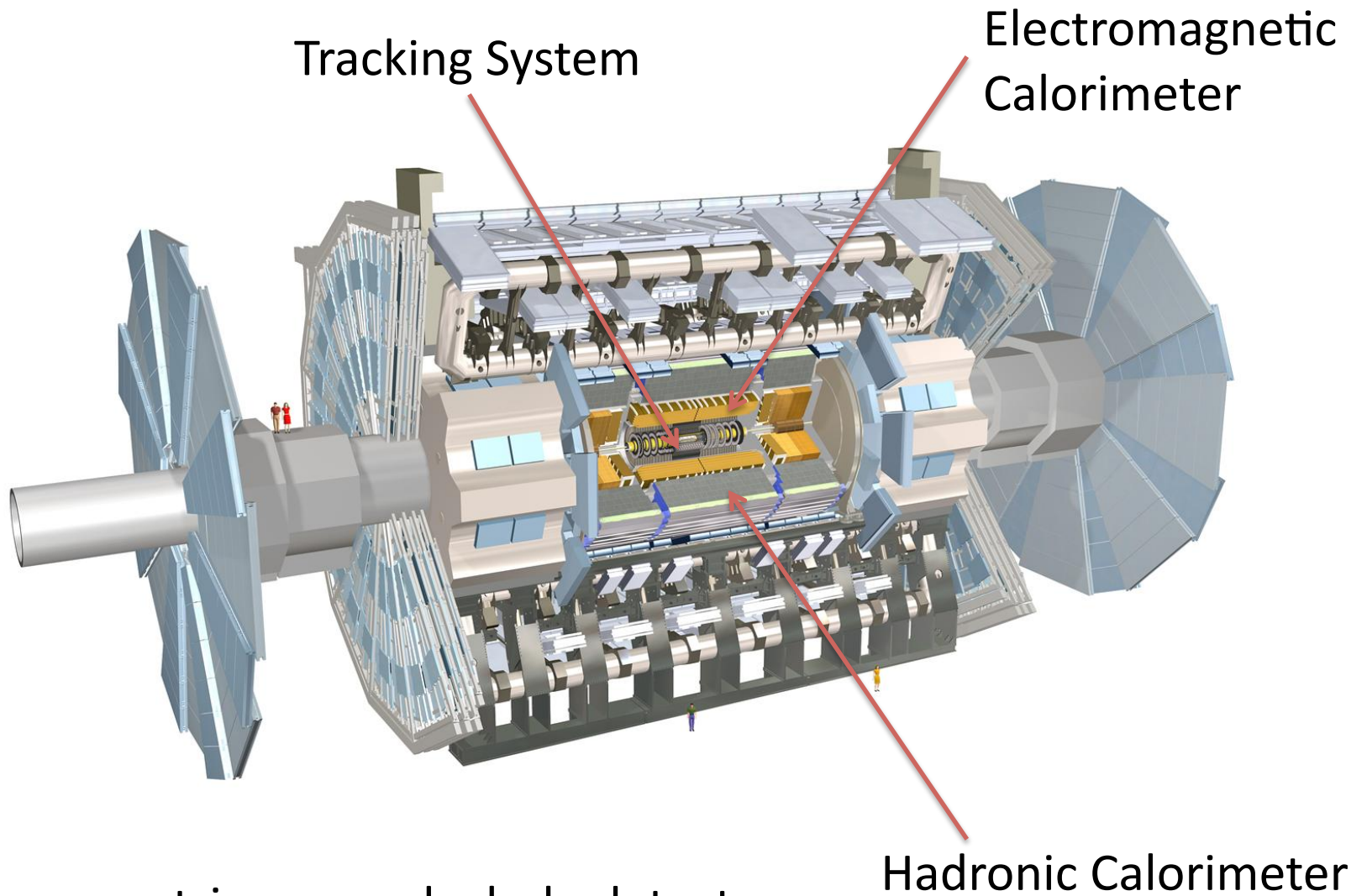
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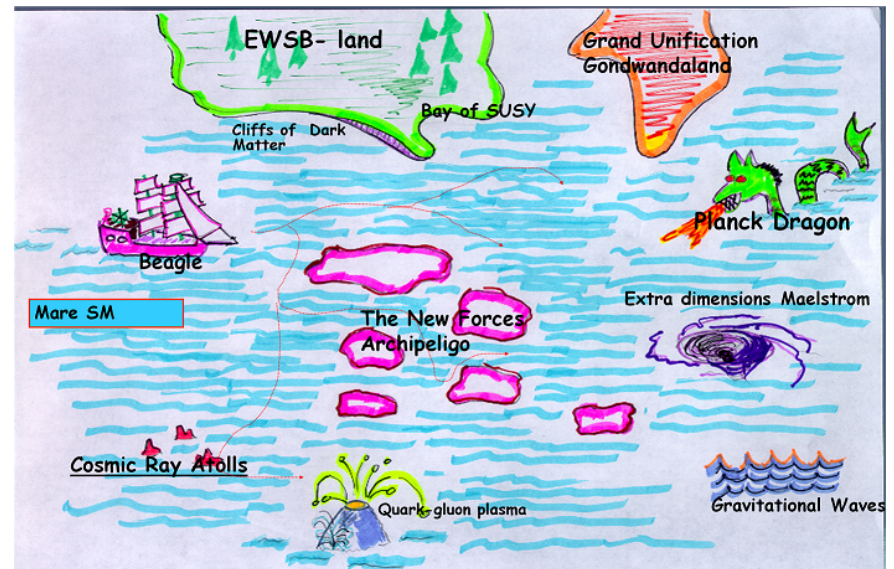


How is ATLAS used in the Leptoquark Search?



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What are the challenges of a leptoquark search?

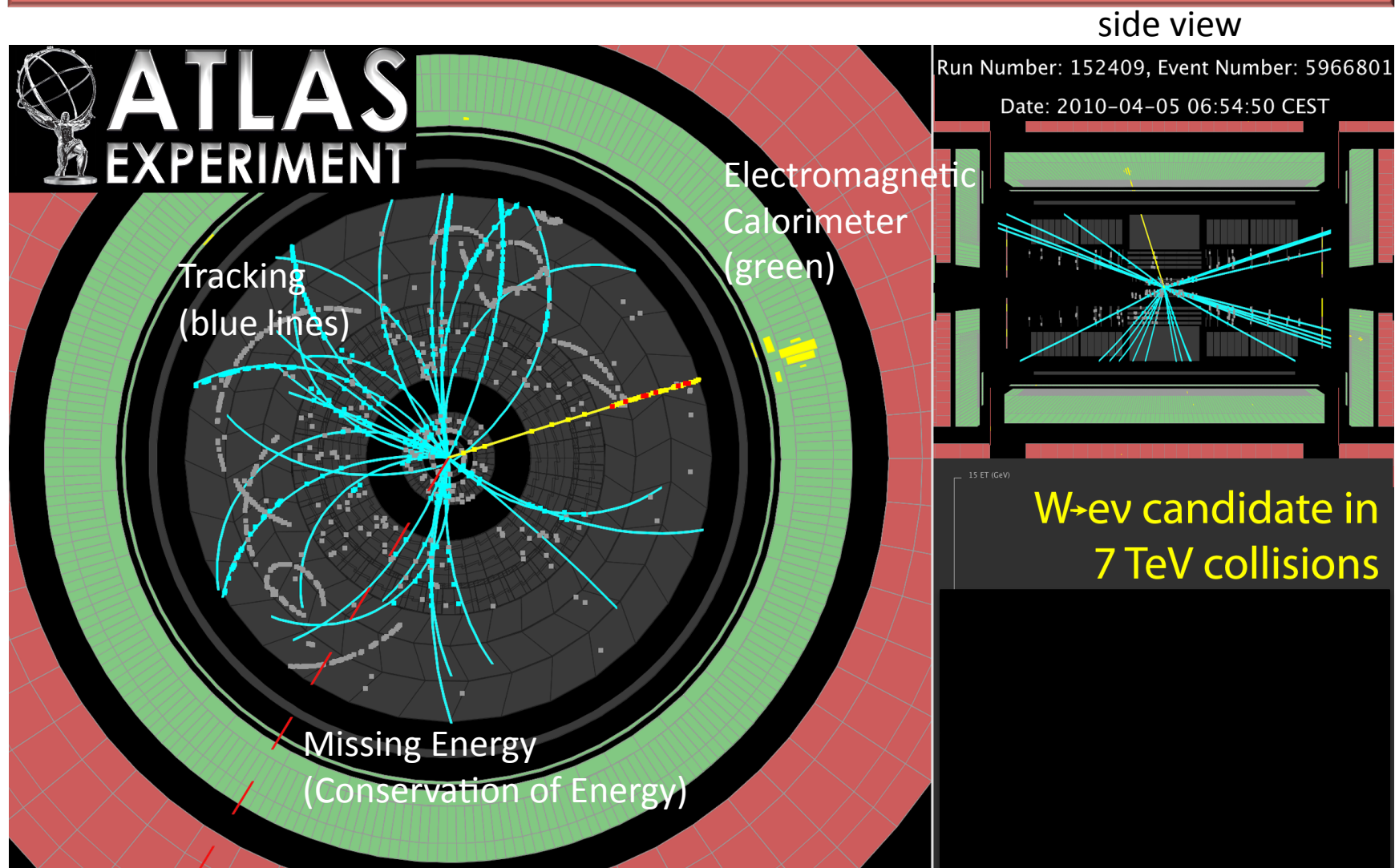
- We predict how leptoquarks decay, but...
 - many known particles decay similarly
 - known particles: higher detection probability
 - Leptoquarks: rare = lower detection probability
- CHALLENGE: find a needle (leptoquark) in a stack of needles



Leptoquark search challenge: the needles

Particle Production	number of events (order of magnitude)
W boson	10,000
Z boson	1,000
top quark	160
Leptoquarks	~1 (we think)

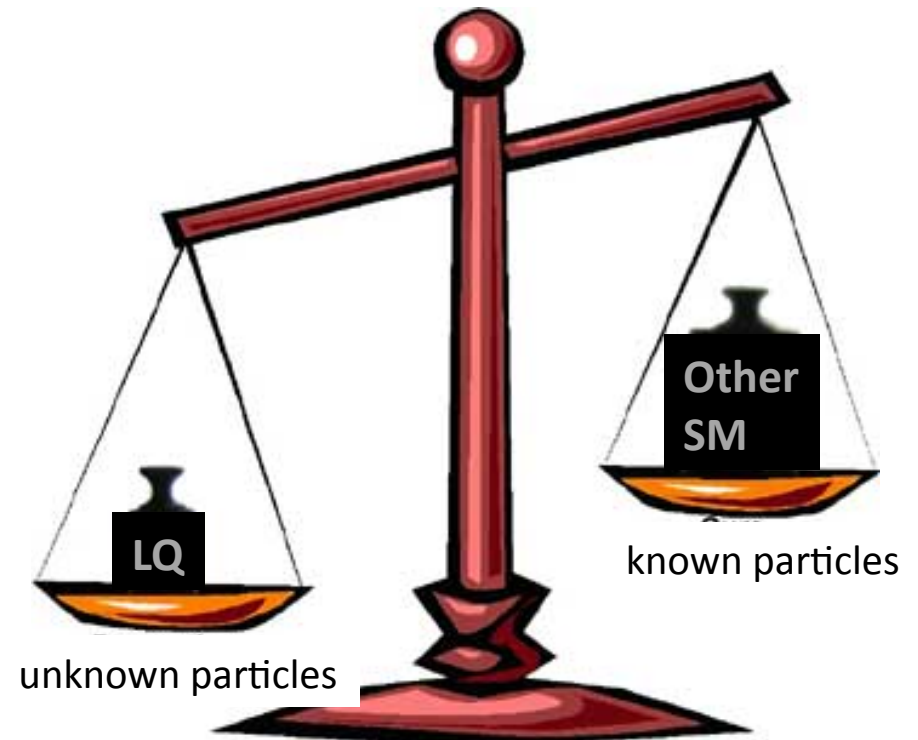
Leptoquark search challenge: ATLAS event display



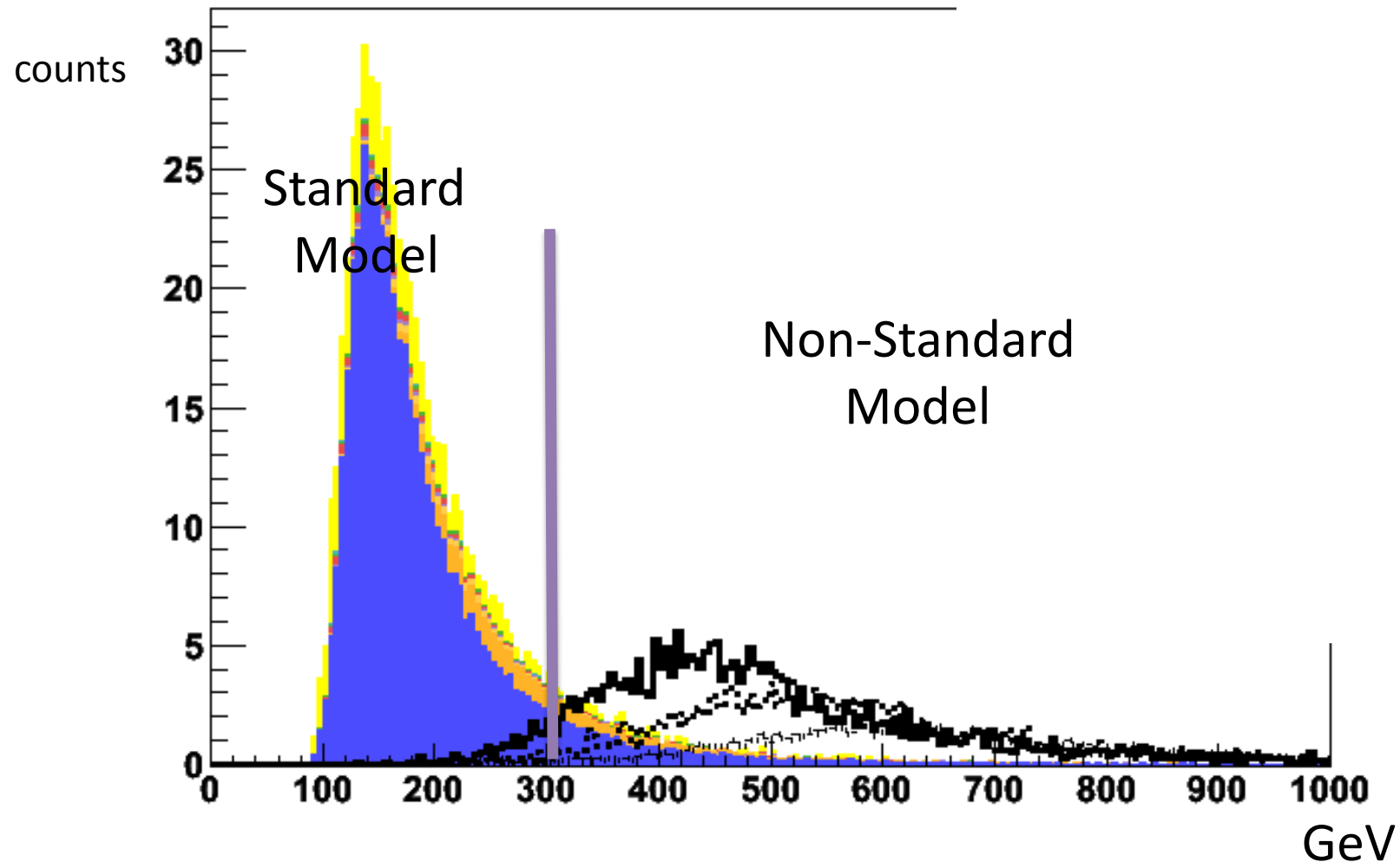
View from the beam

Leptoquark search challenge: How-to

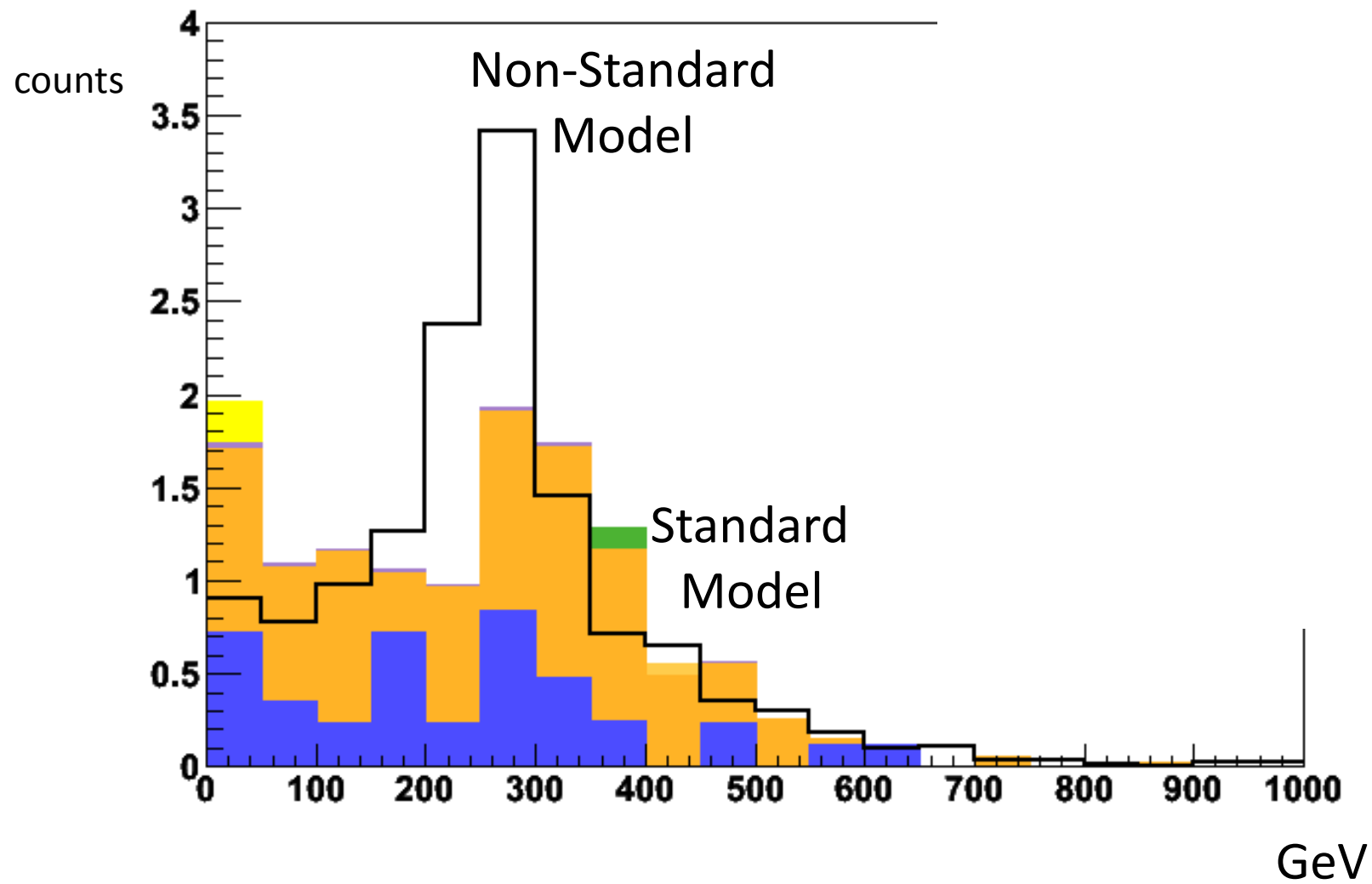
- Find known particles
 - reject these events
- Search for the unknown at the quantum frontier
- Book: *The Quantum Frontier: The Large Hadron Collider*
- My leptoquark search at the quantum frontier



Leptoquark search: Computer-simulated events



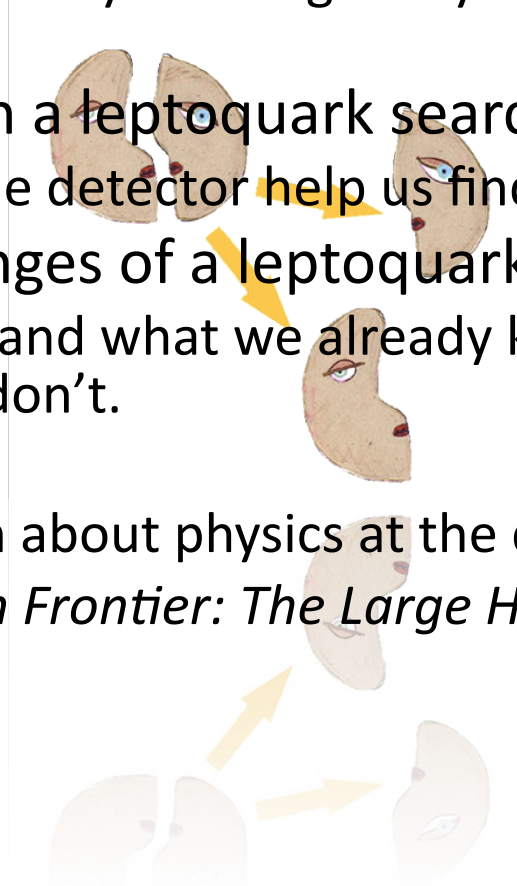
Leptoquark search: Simulated data results



The Importance of Leptoquarks Explained

- Physics Background
 - We've gone from atoms to particles to forces.
- What are Leptoquarks – and why are they important?
 - As physicists we're always looking for symmetries with known particles
- How is ATLAS used in a leptoquark search?
 - Different parts of the detector help us find different particles
- What are the challenges of a leptoquark search?
 - We have to understand what we already know to reject it, and then find what we don't.

For more information about physics at the quantum frontier read
The Quantum Frontier: The Large Hadron Collider



Questions?

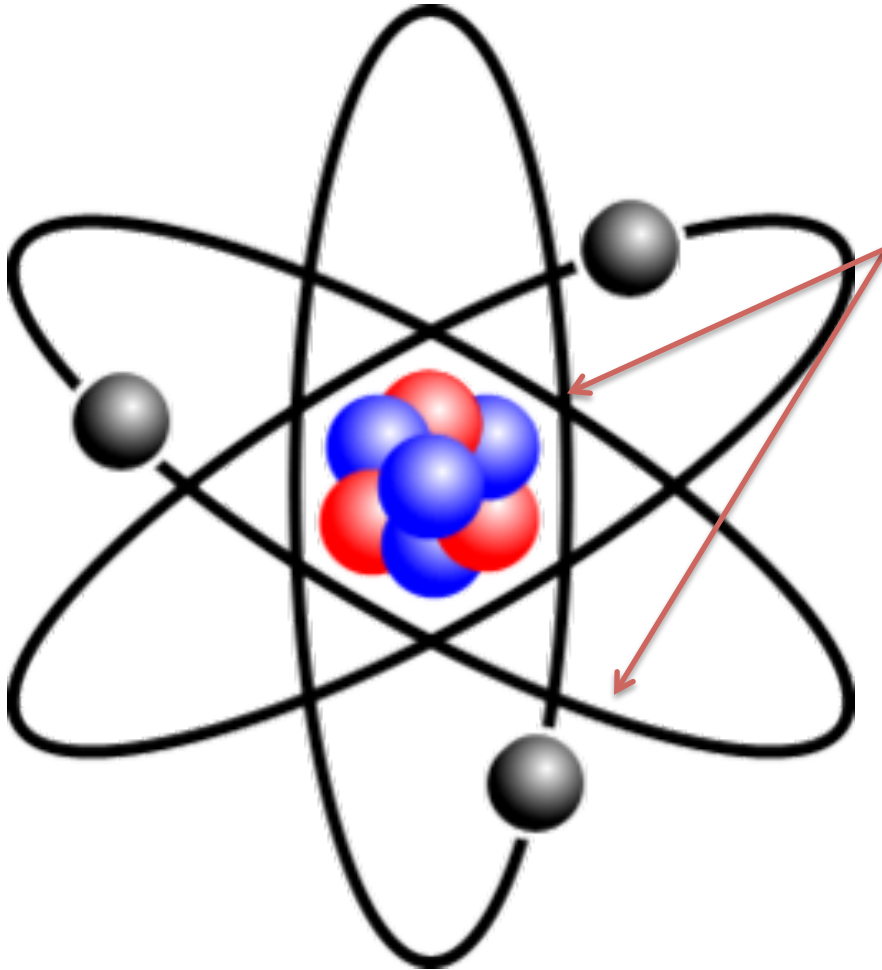


References

- [1] <http://sbhep-nt.physics.sunysb.edu/HEP/AcceleratorGroup/index.html>
- [2] J. Pati and A. Salam, Phys. Rev. D10 (1974), 275
- [3] M. Kramer et al., Phys. Rev. D71, 057503 (2005)
- [4] [arXiv:0907.1048v2](#) [hep-ex]
- [5] [arXiv:hep-ex/0506074v1](#)
- [6] ATLAS TDR, <http://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/TDR/access.html>
- [7] [arXiv:1004.5293v2](#) [physics.ins-det]

Physics Background:

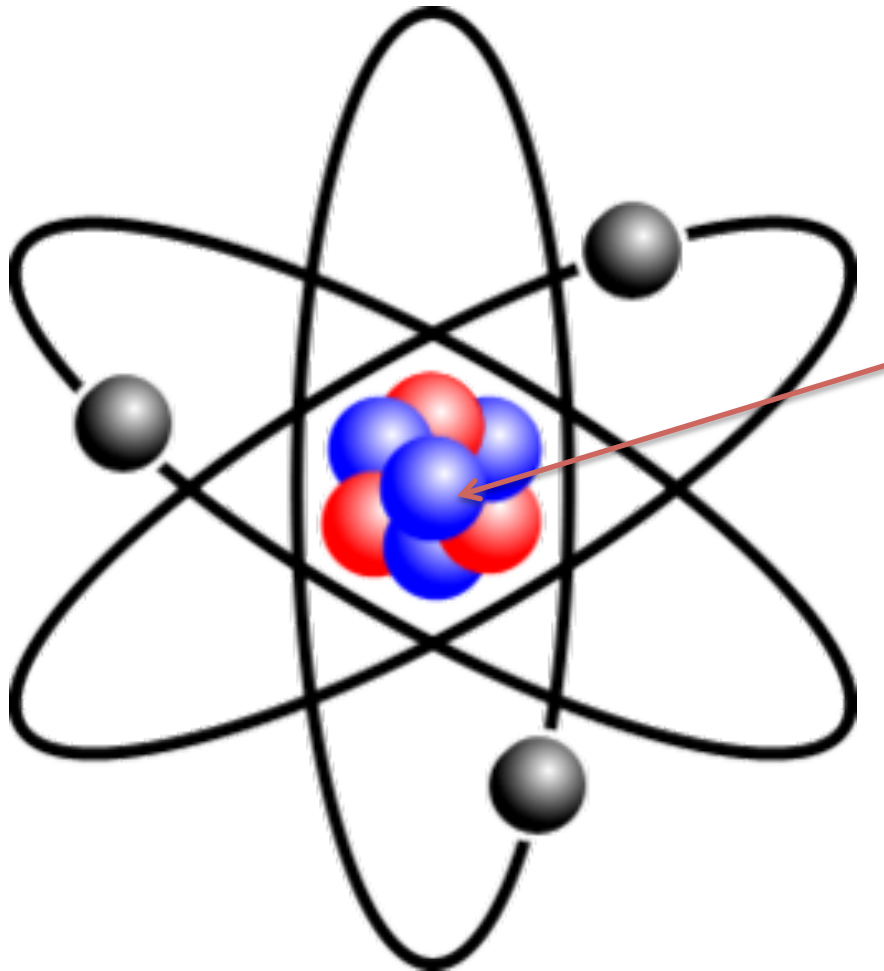
The Four Forces of Nature



- Gravity
- Electromagnetic
 - strength and range:
 - 10^{-3} and infinite
 - governs:
 - charged particles
 - holds atoms together
 - force-carrier:
 - photon
- Weak
- Strong

Physics Background:

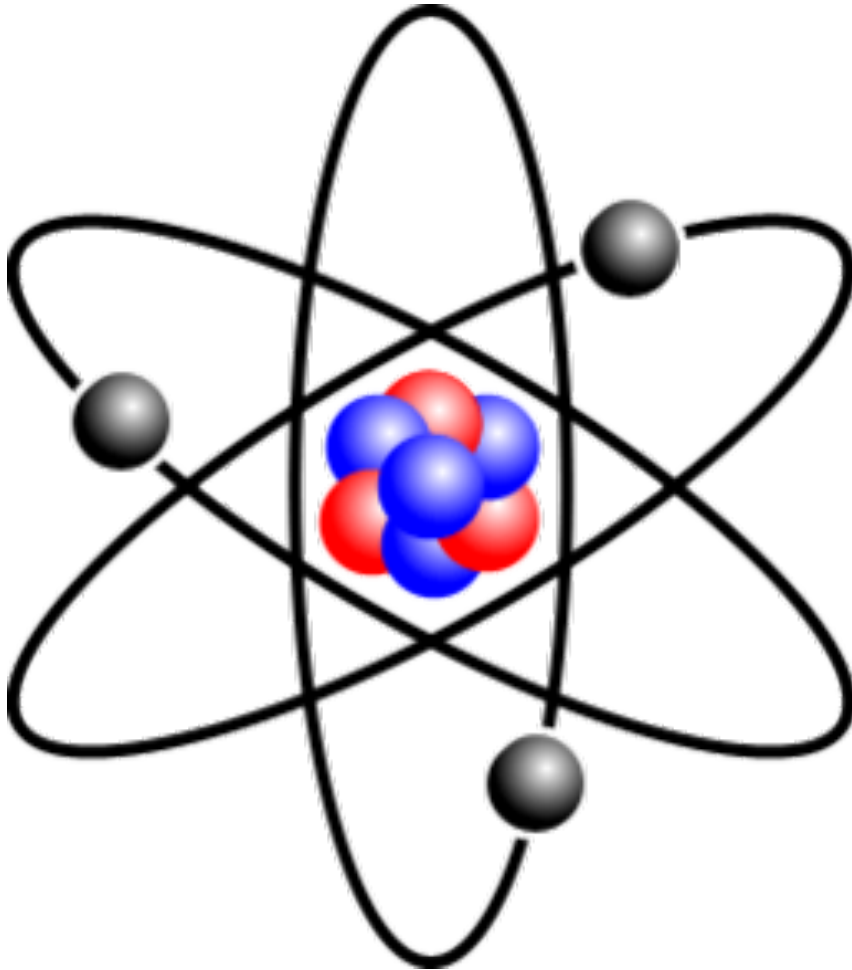
The Four Forces of Nature



- Gravity
- Electromagnetic
- Weak
- Strong
 - strength and range:
 - 1 and 10^{-15} m (\sim nucleus)
 - governs:
 - holds nucleus together
 - color force (unique to quarks)
 - force-carrier:
 - gluon

Physics Background:

The Four Forces of Nature



- Gravity
- Electromagnetic
- Weak
 - strength and range:
 - 10^{-6} and 10^{-18} m ($\sim 0.1\%$ diameter of a proton)
 - governs:
 - beta decay (allows $p \rightarrow n \dots$ which is how sun burns)
 - mixes quark/lepton flavor
 - force carrier:
 - W/Z bosons
- Strong